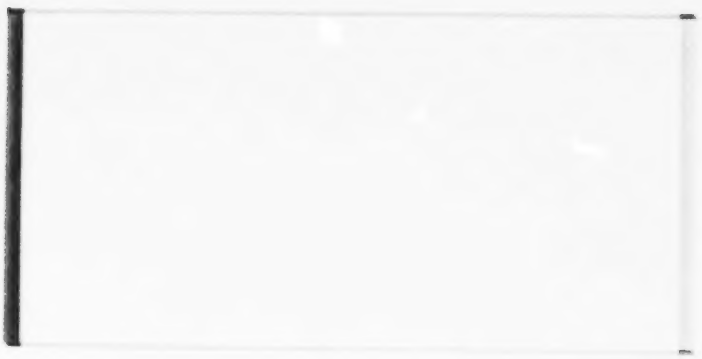
Ontario Hydro



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GALLOPING OCCURRENCES IN CANADA, THE UNITED STATES AND EUROPE DURING THE 1985-86 WINTER

Report No. 86-221-K

C.J. Pon
Engineer
Applied Mechanics Section
Mechanical Research Department

ABSTRACT

The performance of several galloping control devices has been systematically monitored for many years at test sites on lines in Ontario, the United States and Europe. More recently, test sites have been established and are being monitored on distribution and bundle lines across Canada. This report is the latest in a series of reports which describes the performance of galloping control devices on these lines. A total of 11 galloping occurrences were reported during the 1985-86 winter season and are documented in this report.

job	file	date	report no.
740621-302-331	825.151	August 27, 1986	86-221-K

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EXECUTIVE SUMMARY

GALLOPING OCCURRENCES IN CANADA, THE UNITED STATES AND EUROPE DURING THE 1985-86 WINTER

C.J. PON
Engineer
Applied Mechanics Section
Mechanical Research Department

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TABLE OF CONTENTS

		Page
1.0	INTRODUCTION	1
2.0	OBSERVATION OF NOVEMBER 11, 1985 - Orangeville, Ontario	1
3.0	OBSERVATION OF NOVEMBER 29, 1985 - Orangeville, Ontario	2
4.0	OBSERVATIONS OF JANUARY 21, 1986	2
	4.1 Gordon, Manitoba	2
	4.2 Stoney Mountain, Manitoba	3
5.0	OBSERVATION OF JANUARY 22, 1986 - Cheticamp, Nova Scotia	3
6.0	OBSERVATION OF JANUARY 24, 1986 - Maelbroek to Beersdal, Netherlands	3
7.0	OBSERVATIONS OF LATE JANUARY/EARLY FEBRUARY, 1986	4
	7.1 Darwen to Bradford, England	4
	7.2 Darwen, England	5
8.0	OBSERVATION OF FEBRUARY 13, 1986 - Orangeville, Ontario	5
9.0	OBSERVATION OF MARCH 6, 1986 - OPL-02, Newfoundland	5
10.0	OTHER OCCURRENCE - Norway	6
11.0	CONCLUSIONS	6
12.0	ACKNOWLEDGEMENTS	6
	REFERENCES	7
	APPENDIX I	9
	DISTRIBUTION	last page

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To: Dr. D. Mills
Director of Research

GALLOPING OCCURRENCES IN CANADA, THE UNITED STATES AND EUROPE DURING THE 1985-86 WINTER

1.0 INTRODUCTION

This report documents occurrences of conductor galloping at test sites and elsewhere on transmission and distribution lines throughout Canada, the United States and Europe for the 1985-86 winter season. It is the latest in a series of reports/1-9/ which provides a continuing record of galloping observations made by trained observers. The past year produced eleven reported occurrences of galloping; seven in Canada, none in the United States and four in Europe. Five were on distribution lines, one on a single conductor transmission and five on bundle conductor transmission lines.

This report does not interpret the data but serves only to document the observations. Interpretations of these observations should only be considered valid in the context of the accumulated data of each device. Summarizing reports have been issued for drag dampers/10/, interphase spacers/11/ and detuning pendulums/12/. A recent report/13/ has attempted to compare these devices and air flow spoilers based on all data available to the end of 1983. A recent report/14/ and two publications/15,16/ have attempted to apply the results and benefits of these controls to improving line designs.

2.0 OBSERVATION OF NOVEMBER 11, 1985 - Orangeville, Ontario

On November 11, 1985, galloping was observed at Ontario Hydro's Orangeville-M6 distribution test site. This site is included in CEA project 196 D 367 on "Control of Distribution Line Galloping". The site covers 12 spans of a single circuit 44 kV line. Detuning pendulums, interphase spacers, air flow spoilers and aerodynamic tee foils(formerly called Russian tee foil) are installed at this site.

A movie film and written observations provide the details of this occurrence. The temperature was -4 degrees Celsius with the wind from the north-east at 13-19 kph (8-12 mph). The ice thickness was estimated at 25 mm (1 inch). Freezing rain occurred two days before and then the temperature dropped leaving the conductors ice coated until November 12. Only two of the 12 spans were

observed and reported to have galloping motions. The reference phases and those with air flow spoilers and aerodynamic tee foils were still while the one phase with pendulums and the one with interphase spacers galloped at about one foot in 2 and 3 loops respectively. A summary of the observation and a map of the test site are contained in Appendix I.

3.0 OBSERVATION OF NOVEMBER 29, 1985 - Orangeville, Ontario

On November 29, 1985, galloping was observed again at the Orangeville-M6 site. Three movie films and written observations were taken of this occurrence. The temperature was -4 degrees Celsius with the wind from the south-east at 16-32 kph (10-20 mph). Hoarfrost with a triangular cross section coated the conductors and was estimated to be 19 mm (3/4 inches) thick at the apex. Combined horizontal and twisting motions were observed on the phases installed with detuning pendulums. The horizontal amplitude was estimated at 0.3-0.6 m (1-2 feet) in single loop. There was a coupling of two torsional cycles for every one horizontal cycle. The reference phase and the phase with air flow spoilers on the same spans were still. A summary of the observation is contained in Appendix I.

4.0 OBSERVATIONS OF JANUARY 21,1986

4.1 Gordon Test Site

On January 21, 1986, galloping was observed on Manitoba Hydro's 500 kV, 3 conductor bundle Gordon test site. This site is part of CEA project 133 T 386 "Field Trials of Galloping Control Devices for Bundle Conductor Lines". It is a single circuit line and the site covers six spans. Three spans have detuning pendulums installed on one phase and three spans have interphase spacers installed between two phases.

A written report and movie film were taken by Manitoba Hydro staff to document this occurrence. The temperature was -12 degrees Celsius with the wind from the north at 21-24 kph (13-15 mph). Clear ice with a thickness of 3.2 mm (1/8 inches) was measured on structure members. The skies were clear with a light cloud cover. Two reference phases were galloping with amplitudes up to 10.7 m (35 ft) in two loops. The phase with the detuning pendulums were still for a period of time. When the wind increased, however, this phase started to gallop and attained amplitudes of 6.1 m (20 feet). The amplitudes of the phases with the interphase spacers also reached 6.1 m (20 feet) while the one reference phase galloped at 7.6 m (25 feet). During a maintenance outage in April, the line was inspected and insulators were removed and tested. There was no mechanical or electrical damage detected except for a broken bonding wire on one of the interphase spacers. A summary of the observation and a map of the test site are contained in Appendix I.

4.2 Stoney Mountain Test Site

The same storm system also caused mild galloping at Manitoba Hydro's Stoney Mountain test site. This site is also included in the CEA bundle galloping project. It is a two bundle, 230 kV single circuit line and detuning pendulums are installed on three spans.

Written observations were taken during this occurrence. The temperature was -12 degrees Celsius and the wind was blowing from the north at 21-24 kph (13-15 mph). Clear ice with a thickness of 3.2 mm (1/8 inches) was measured off structure members. The skies were clear with a light cloud cover. The two reference phases were reported galloping at 0.6 m (2 feet) while the detuned phase remained still. A summary of the observation and a map of the test site are contained in Appendix I.

5.0 OBSERVATION OF JANUARY 22, 1986 - Cheticamp, Nova Scotia

On January 22, 1986, galloping was reported at the Cheticamp test site in Nova Scotia. This site is also part of the CEA project on distribution line galloping. The site covers 10 spans of a single circuit 12 kV line. Detuning pendulums, interphase spacers and air flow spoilers are installed at this site.

Written observations and movie film were taken during the occurrence. The temperature was 1 degree Celsius with the wind blowing from the NNW at 24-29 kph (15-18 mph). There was about 9.5 mm (3/8 inches) of ice on the conductors. The weather had freezing rain and sleet conditions. From the movie film, the galloping intensity seemed to increase and decrease. Some reference phases remained relatively still while others were galloping with amplitudes up to 30 cm (1 foot) in two loops. The detuning pendulums in some spans were almost still while amplitudes of up to 30 cm (1 foot) in single loop were observed elsewhere. The air flow spoilers held motions to very low levels throughout the observation. The phases with interphase spacers exhibited slight motions up to 15 cm (6 inches) in two loops. A node seemed to be created at the attachment points so the spacer experienced only small movements. Some time after the galloping, a failed spacer was discovered. It could not be confirmed if the spacer failed during the galloping, however, it seems likely that the small motions it experienced may have contributed to fatigue of the insulating material. A summary of the observation and a map of the test site are contained in Appendix I.

6.0 OBSERVATION OF JANUARY 24, 1986 - Maelbroek to Beersdal, Netherlands

On January 24, 1986, galloping occurred on the Maalbroek-Beersdal 150 kV, two conductor bundle test site in the Netherlands. The report was sent to Ontario Hydro through the cooperative program of the CORECH working group on conductor galloping. Five of the six phases of this double circuit line are treated with the following control methods.

Phase 1) detuning pendulums on a spacered vertical bundle
Phase 2) rotating clamp spacers on a vertical bundle
Phase 4) despacered horizontal bundle with hoop spacers
Phase 5) despacered vertical bundle
Phase 6) coupled vertical bundle with air flow spoilers

Phase 3) is a spacered vertical phase and is considered untreated and to be used for reference.

On one structure at this site, a recording station was constructed to record the loads on the suspension strings and the weather during galloping. If certain load and weather conditions are met, a signal alerts trained observers to go to the site and record the action on the line. In this particular instance, observers did not take observations.

The temperature during the galloping was 1 degree Celsius with winds of 36 - 54 kph (22.5 - 34 mph). Wet snow had accumulated on the lines during the galloping and ranged in thickness from 0.75 cm (0.3 inches) with a circular profile to 2.7 cm (1.06 inches) with an eccentric profile.

Galloping did not occur on the phases with detuning pendulums, rotating clamp spacers, hoop spacers and despacering. Severe galloping did occur on the reference phase. The maximum amplitude was derived from the measured dynamic loading of the insulator string and was calculated to be 7.5 m (24.6 ft). Galloping also occurred on the phase with air flow spoilers. The calculated amplitude in this case was 6 m (19.7 ft)*. A summary of this occurrence is contained in Appendix I.

7.0 OBSERVATIONS OF LATE JANUARY/EARLY FEBRUARY, 1986

7.1 Darwen to Bradford

Severe galloping persisted for 4 to 5 days on the CEGB system in England from the end of January into the first couple of days in February. The affected line runs through the Pennines in CEGB's Northwest Region from Darwen to Bradford and has no galloping control devices installed. This line has two four conductor bundle circuits; one operating at 400 kV and the other at 275 kV.

A well produced videotape was taken during and after the galloping. The most severe galloping occurred on the sections of line with altitudes over 300 m above sea level. The temperature was at the freezing point with the wind from north-east gusting to 35 kph (22 mph). Although not stated, it is clear from the

---

* In subsequent discussions with the supplier the airflow spoiler treatment is about 50% of the currently recommended level.

video that there was a substantial amount of ice on the tower members and other hardware components. The span with the most severe motions were videotaped and showed all phases galloping in single loop with some phases slightly above horizontal at maximum displacement. Utility personnel at the site estimated these amplitudes at about 9.1 m (30 ft). The span lengths in this area are of the order of 300 m (1000 ft).

Damage to this line was extensive as the video shows loose and broken tower members, a broken insulator string and broken jumpers. The line was out of service for about 2 months. Detuning pendulums have been designed for 70 spans of this line and CEGB are proceeding with the manufacture and installation of these devices. A summary of this observation is contained in Appendix I.

7.2 Darwen

At approximately the same time as the above occurrence, galloping was observed by an untrained observer at a two conductor bundle, 400 kV pendulum test site.

A written account of the galloping with limited details is the only source for documentation. The wind was estimated at 32 - 48 kph (20 -30 mph). The observation was made on a 329 m (1080 ft) tension-suspension span. The top detuned phase was relatively stable while the middle and bottom reference phases were galloping at an estimated peak-to-peak amplitude of 1.2 m (4 ft) with a mixture of two and three loops. A summary of this observation is contained in Appendix I.

8.0 OBSERVATION OF FEBRUARY 13, 1986 - Orangeville, Ontario

On February 13, 1986, galloping was observed on two sections of 7.2 kV single phase distribution line near Orangeville, Ontario. There are no control devices installed on these sections.

A written report and two movie films were taken during this occurrence. The temperature was -10 degrees Celsius and the winds were gusting to 16 kph (10 mph) from the north-west. The ice had a triangular cross section and a thickness between 12.7 - 19.1 mm (1/2 - 3/4 inches). The ice was deposited on the south side of the conductor indicating that there had been a shift in wind direction. The 3/0 conductor was observed to be galloping at amplitudes up to 0.91 m (3 ft) in one section and up to 0.76 m (2.5 ft) in the other section. Both sections were galloping in single loop. A summary of the observation is contained in Appendix I.

9.0 OBSERVATION OF MARCH 6, 1986 - OPL-02, Newfoundland

On March 6, 1986, galloping was observed on Newfoundland Light and Power's OPL-02, 12.5 kV, single circuit distribution line.

Air flow spoilers are installed on one phase of this three phase line. This site is not officially included in the CEA distribution line galloping project.

Written observations and a movie film were taken during the galloping. The temperature was -2 degrees Celsius with the wind from the north-west at 118 kph (74 mph). There was no ice recorded at the time of the observation but subsequent discussions with the observers indicated the possibility of a very thin coating on the conductors. The two reference phases experienced mild two loop galloping with amplitudes up to 0.25 m (10 inches). The phase with the air flow spoilers remained still. A summary of the observation is contained in Appendix I.

10.0 OTHER OCCURRENCE

Very limited detail is available at this writing on some action at a detuning pendulum site in Norway. It was reported that some of the pendulums have been rotated 270 - 330 degrees. The cause is suspected to be galloping coupled with some sideways movement of the conductor.

11.0 CONCLUSIONS

Recorded observations of galloping occurrences on lines across Canada, the United States and Europe have been documented for the 1985-86 winter season. As stated, this report does not attempt to interpret the observational data. The conclusions made in references 9,10,11 and 12 indicate that the air flow spoiler, the modified drag damper, the interphase spacer and the detuning pendulum show promise at reducing galloping amplitudes. The data contained herewith do not change these conclusions.

12.0 ACKNOWLEDGEMENTS

The author wishes to express his appreciation to the people who made the observations documented in this report.

Approved by:

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Manager
Mechanical Research Dept

Submitted by:

C.J. Pon
Engineer
Applied Mechanics Section

Reviewed by:

D.G. Havard
Senior Research Engineer
Applied Mechanics Section

JOT

REFERENCES

1. D.G. Havard, "Review of Field Trials of Galloping Control Devices Based on the Torsional Mechanism, 1971-1977" Ontario Hydro Research Division Report No 77-564-K.

2. J.A. Chadha, D.G. Havard, A.T. Edwards, "Observations of Performance of Galloping Control Devices - December 18, 1977", Ontario Hydro Research Division Report No 78-75-K.

3. D.G. Havard, "Observations of Performances of Galloping Control Devices 1978-79 Winter", Ontario Hydro Research Division Report No 79-276-K.

4. D.G. Havard, E.P. Stasiuk, "Observations of Performances of Galloping Control Devices on Ontario Hydro Lines 1979-80 Winter", Ontario Hydro Research Division Report No B80-170-K.

5. C.J. Pon, "Performance of Galloping Control Devices on Ontario Hydro Lines 1981-82 Winter, Ontario Hydro Research Division Report No B82-52-K.

6. C.J. Pon, "Performance of Galloping Control Devices on Ontario Hydro Lines 1982-83 Winter", Ontario Hydro Research Division Report No 83-461-K.

7. C.J. Pon, "Performance of Galloping Control Devices on Ontario Hydro Lines 1983-84 Winter" Ontario Hydro Research Division Report No B84-60-K.

8. C.J. Pon, "Galloping Occurrences in Canada and the United States During the 1984-85 Winter" Ontario Hydro Research Division Report No 85-276-K.

9. D.G. Havard, EPRI Research Program RP-1095 Galloping Control by Detuning - Progress Report No 4, 1981".

10. R.G. Ko, "Performance of the Modified Drag Damper (MDD) as a Galloping Control Device", Ontario Hydro Research Division Report No 80-270-K.

11. C.J. Pon, D.G. Havard, A.T. Edwards, "Performance of Interphase Spacers for Galloping Control", Ontario Hydro Research Division Report No 82-216-K.

12. D.G. Havard, J.C. Pohlman, "Five Years' Field Trials of Detuning Pendulums for Galloping Control", IEEE Paper 83SM470-2.

13. D.G. Havard, "Progress in Field Research on Control of Galloping of Iced Conductors", Ontario Hydro Research Division Report No 84-221-K.

14. D.G. Havard, "Hanmer-Mississagi 230/500 kV Line Galloping Clearance", Ontario Hydro Research Division Report No 85-241-K.

15. D.G. Havard, C.J. Pon, J.C. Pohlman, "Reduction of Tower Head Dimensions Through Galloping Controls", 3rd International Workshop on the Atmospheric Icing of Structures, Vancouver, BC, Canada, May 1986.

16. D.G. Havard, C.J. Pon, G.S. Watt, "Clearances for Galloping on Overhead Lines", International Symposium on Probabilistic Methods Applied to Electric Power Systems, Toronto, Ontario, Canada, June 1986.

APPENDIX I

SUMMARY OF 1985-86 GALLOPING OBSERVATIONS

DATA FROM FIELD OBSERVATIONS OF GALLOPING

OBSERVATION NO. S64 PAGE: 1 of 1 DATE: Nov. 11/85

UTILITY: Ontario Hydro	SITE: Orangeville - M6	VOLTAGE: 44 kV	LINE DIR'N: N-S
CONDUCTOR NAME: ASC-Dahlia	COND'R DIAMETER: 21.7 mm 0.856 in	COND'R CONST: 19 Strands	
CONDUCTOR SIZE: 556.5 kcmil	COND'R WT. 0.774 kg/m 0.522 lb/ft	AREA OF ALUM: 282 mm^2 .4371 in^2	
NO OF SUBCONDUCTORS: 1	SUBCOND'R SPACING: - mm - in	AREA OF STEEL: - mm^2 - in^2	
TENSION AT 0°C 6.4 kN 1440 lb	TORS'L STIFF: 31 $N \cdot m^2/r$ 74 $lb \cdot ft^2/r$	ICE SHAPE, POSITION	
PENDULUM WT./SPAN: 23.3 kN 51.4 lb	NO OF LOCATIONS PER SPAN: 4		
PENDULUM ARM LENGTH: 321 mm 12.63 in	RADIUS OF GYRATION: 333 mm 13.1 in		
WEATHER: No Precipitation	WIND SPEED: 3.6-5.3 m/s 8-12 mph		
TEMPERATURE: -4 °C 25 °F	WIND DIRECTION: NE to SW	ICE THICKNESS: 25.4 mm 1.0 in	

TIME	SPAN, TOWER NOs	SPAN LENGTH m ft	SAG m ft	GALLOPING AMPLITUDE: m ft NUMBER OF LOOPS								MAX'M THEOR AMPL. m ft	PROT'N LEVEL at $F_v = 1$, $F_t = 1$
				IPS	DP	AFS	ATF	REF	REF	REF	REF		
				U-L *	L *	U *	L *	M *	*	*	*		
9:15 am	10	76.2 250		0.30 1.0 3	- - -	- - -	- - -	0 0 0					-
9:30 am	2	76.2 250		- - -	0.30 1.0 2	0 0 0	- - -	0 0 0					18.5

Note: The phases with air flow spoilers, aerodynamic tee foils and all reference phases were still during this observation.

IPS - Interphase spacer
DP - Detuning Pendulum
AFS - Air Flow Spoiler
ATF - Aerodynamic Tee Foil
REF - Reference Phase

* PHASE LOCATION: N-North, S-South, E-East, W-West, U-Upper, M-Middle, L-Lower, I-Inner, O-Outer

DATA FROM FIELD OBSERVATIONS OF GALLOPING

OBSERVATION NO. S65 PAGE: 1 of 1 DATE: Nov. 29/85

UTILITY: Ontario Hydro	SITE: Orangeville - M6	VOLTAGE: 44 kV	LINE DIR'N: N-S
CONDUCTOR NAME: ASC-Dahlia	COND'R DIAMETER: 21.7 mm 0.856 in	COND'R CONST: 19 Strands	
CONDUCTOR SIZE: 556.5 kcmil	COND'R WT. 0.774 kg/m 0.522 lb/ft	AREA OF ALUM: 282 mm^2 .4371 in^2	
NO OF SUBCONDUCTORS: 1	SUBCOND'R SPACING: - mm - in	AREA OF STEEL: - mm^2 - in^2	
TENSION AT 0°C 6.4 kN 1440 lb	TORS'L STIFF: 31 $N \cdot m^2/r$ 74 $lb \cdot ft^2/r$	ICE SHAPE, POSITION	
PENDULUM WT./SPAN: 23.3 kN 51.4 lb	NO OF LOCATIONS PER SPAN: 4		
PENDULUM ARM LENGTH: 321 mm 12.63 in	RADIUS OF GYRATION: 333 mm 13.1 in		
WEATHER: Cloudy, Windy	WIND SPEED: 4.4-8.4 m/s 10-20 mph		
TEMPERATURE: -4 °C 25 °F	WIND DIRECTION: from SE	ICE THICKNESS: 19 mm .75 in (Hoarfrost)	

TIME	SPAN, TOWER NOs	SPAN LENGTH m ft	SAG m ft	GALLOPING AMPLITUDE: m ft NUMBER OF LOOPS								MAX'M THEOR AMPL. m ft	PROT'N LEVEL at $F_v = 1$, $F_t = 1$
				DET'D	AFS	REF	REF	REF	REF	REF	REF		
				L *	U *	M *	*	*	*	*	*		
10:20 am	1	76.2 250		.3 - .6 1-2 1	0 0 0	0 0 0							0.185
10:30 am	2	76.2 250		.3 - .6 1-2 1	0 0 0	0 0 0							0.185
0:40 am	4	76.2 250		.3 - .6 1-2 1	0 0 0	0 0 0							0.185

Note: Galloping on detuned phases is in horizontal. There was a coupling of two horizontal cycles for every one horizontal cycle.

DET'D - Detuning Pendulum
AFS - Air Flow Spoiler
REF - Reference Phase

* PHASE LOCATION: N-North, S-South, E-East, W-West, U-Upper, M-Middle, L-Lower, I-Inner, O-Outer

CEA

DISTRIBUTION LINE GALLOPING OBSERVATION DATA SHEET

Utility Name: ONTARIO HYDRO

Test Site Name: M6

Date of Observation: _____

Observed by: _____

Conductor Size (s): 556.5 kcmil

Wind Speed: _____

Wind Direction: from _____ to _____

Air Temperature: _____

Ice Thickness (est'd): _____

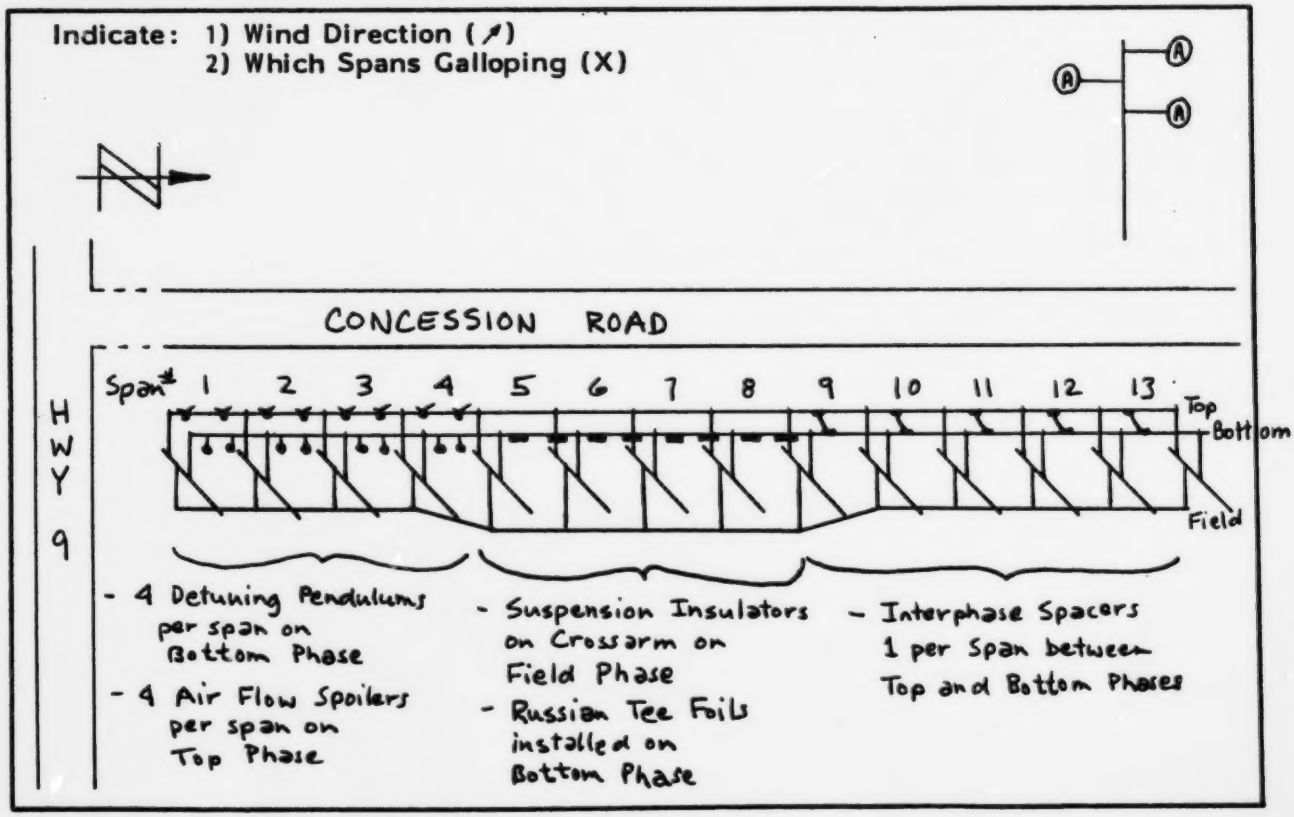
General Weather Conditions: _____

_____

_____

Please provide Test Site Map

Indicate: 1) Wind Direction (↗)
2) Which Spans Galloping (X)


A
A
A
CONCESSION ROAD
Span # 1 2 3 4 5 6 7 8 9 10 11 12 13
Top
Bottom
Field
HWY 9
- 4 Detuning Pendulums per span on Bottom Phase
- 4 Air Flow Spoilers per span on Top Phase
- Suspension Insulators on Crossarm on Field Phase
- Russian Tee Foils installed on Bottom Phase
- Interphase Spacers 1 per Span between Top and Bottom Phases

Return completed form to: C.J. Pon
Ontario Hydro Research Division
800 Kipling Avenue, KR284
Toronto, Ontario M8Z 5S4

DATA FROM FIELD OBSERVATIONS OF GALLOPING

OBSERVATION NO. B34 PAGE: 1 of 1 DATE: Jan. 21/86

UTILITY: Manitoba Hydro		SITE: Gordon		VOLTAGE: 500 kV	LINE DIR'N: E-W
CONDUCTOR NAME: ACSR-Pheasant		COND'R DIAMETER: 35.1 mm 1.382 in		COND'R CONST: 54/19	
CONDUCTOR SIZE: 1272 kcmil		COND'R WT. 2.44 kg/m 1.635 lb/ft		AREA OF ALUM: 638.7 mm^2 0.99 in^2	
NO OF SUBCONDUCTORS: 3		SUBCOND'R SPACING: 457 mm 18 in		AREA OF STEEL: 87.7 mm^2 0.136 in^2	
TENSION AT 0°C 38.0 kN 8543 lb		TORS'L STIFF: $N \cdot m^2/r$ 1465 $lb \cdot ft^2/r$		ICE SHAPE, POSITION	
PENDULUM WT./SPAN: 91 kN 200 lb		NO OF LOCATIONS PER SPAN: 2			
PENDULUM ARM LENGTH: 457 mm 18 in		RADIUS OF GYRATION: 508 mm 20 in			
WEATHER: Clear Skies		WIND SPEED: 5.8-6.7 m/s 13-15 mph			
TEMPERATURE: -12 °C 10.4 °F		WIND DIRECTION: from North		ICE THICKNESS: 3.2 mm 1/8 in (Hoarfrost)	

TIME	SPAN, TOWER NOs	SPAN LENGTH m ft	SAG m ft	GALLOPING AMPLITUDE: m ft NUMBER OF LOOPS								MAX'M THEOR AMPL. m ft	PROT'N LEVEL at $F_v = 1$, $F_t = 1$
				DET'D	IPS	REF	REF	REF	REF	REF	REF		
				N *	N-U *	U *	S *	*	*	*	*		
9:30 am	25-26	417	13.6	0	-	10.7	4.6					-	12
				0	-	35	15						
		1368	44.8	0	-	2	2						
10:00 am	25-26	417	13.6	6.1	-	10.7	7.6					-	12
				20	-	35	25						
		1368	44.8	*	-	*	*						
11:00 am	28-29	438	15.1	-	6.1	-	7.6						
				-	20	-	25						
		1437	49.4	-	*	-	*						

DET'D - Detuning Pendulum
IPS - Interphase Spacer
REF - Reference Phase

* Random Motions

* PHASE LOCATION: N-North, S-South, E-East, W-West, U-Upper, M-Middle, L-Lower, I-Inner, O-Outer

M-365(a)

CEA

BUNDLE LINE GALLOPING OBSERVATION DATA SHEET

Utility Name: Manitoba Hydro

Test Site Name: Gordon (500 kV)

Date of Observation: _____

Observed by: _____

No. of Subconductors: 3

Subconductor Size : 1272 MCM, 54/19, 1.382" Dia., 1.628 lbs/ft

Wind Speed: _____

Wind Direction: from _____ to _____

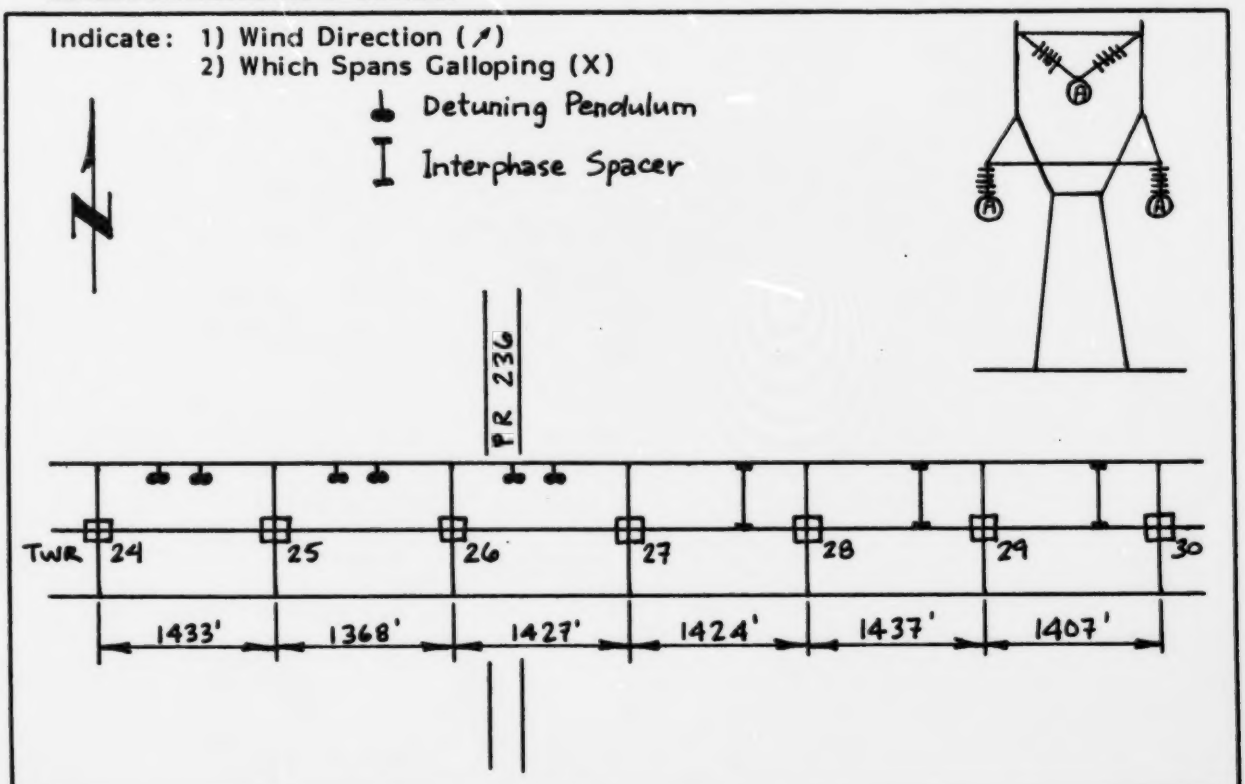
Air Temperature: _____

Ice Thickness (est'd): _____

General Weather Conditions: _____

Please provide Test Site Map

Indicate: 1) Wind Direction (↗)
2) Which Spans Galloping (X)



Return completed form to: C.J. Pon
Ontario Hydro Research Division
800 Kipling Avenue, KB223
Toronto, Ontario M8Z 5S4

86-221

DATA FROM FIELD OBSERVATIONS OF GALLOPING

OBSERVATION NO. B35 PAGE: 1 of 1 DATE: Jan. 21/86

UTILITY: Manitoba Hydro	SITE: Stoney Mountain	VOLTAGE: 230 kV	LINE DIR'N: E-W
CONDUCTOR NAME: ACSR	COND'R DIAMETER: 25.4 mm 1.0 in	COND'R CONST: 22/7	
CONDUCTOR SIZE: 685 kcmil	COND'R WT. 1.23 kg/m 0.822 lb/ft	AREA OF ALUM: mm^2	in^2
NO OF SUBCONDUCTORS: 2	SUBCOND'R SPACING: 406 mm 16 in	AREA OF STEEL: mm^2	in^2
TENSION AT 0°C 18.3 kN 4114 lb	TORS'L STIFF: $N \cdot m^2/r$ 500 $lb \cdot ft^2/r$	ICE SHAPE, POSITION	
PENDULUM WT./SPAN: 68 kN 150 lb	NO OF LOCATIONS PER SPAN: 3		
PENDULUM ARM LENGTH: 226 mm 8.9 in	RADIUS OF GYRATION: 231 mm 9.1 in		
WEATHER: Clear	WIND SPEED: 5.8-6.7 m/s 13-15 mph		
TEMPERATURE: -12 °C 10.4 °F	WIND DIRECTION: from North	ICE THICKNESS: 3.2 mm	1/8 in

TIME	SPAN, TOWER NOs	SPAN LENGTH m / ft	SAG m / ft	GALLOPING AMPLITUDE: m / ft — NUMBER OF LOOPS								MAX'M THEOR AMPL. m / ft	PROT'N LEVEL at $F_V = 1$, $F_T = 1$
				DET'D	REF	REF	REF	REF	REF	REF	REF		
				N *	M *	S *	*	*	*	*	*		
10:45 am	405-406	384 1260	12.1 39.7	0 0 0	.61 2 N/A	.61 2 N/A							12

DET'D - Detuning Pendulum
REF - Reference Phase

* PHASE LOCATION: N-North, S-South, E-East, W-West, U-Upper, M-Middle, L-Lower, I-Inner, O-Outer

M-365(a)

CEA

BUNDLE LINE GALLOPING OBSERVATION DATA SHEET

Utility Name: Manitoba Hydro

Test Site Name: Stoney Mountain (230 kV)

Date of Observation: _____

Observed by: _____

No. of Subconductors: 2

Subconductor Size: 685 MCM, 22/7 ACSR, 1.0" Dia., 0.822 lbs/ft

Wind Speed: _____

Wind Direction: from _____ to _____

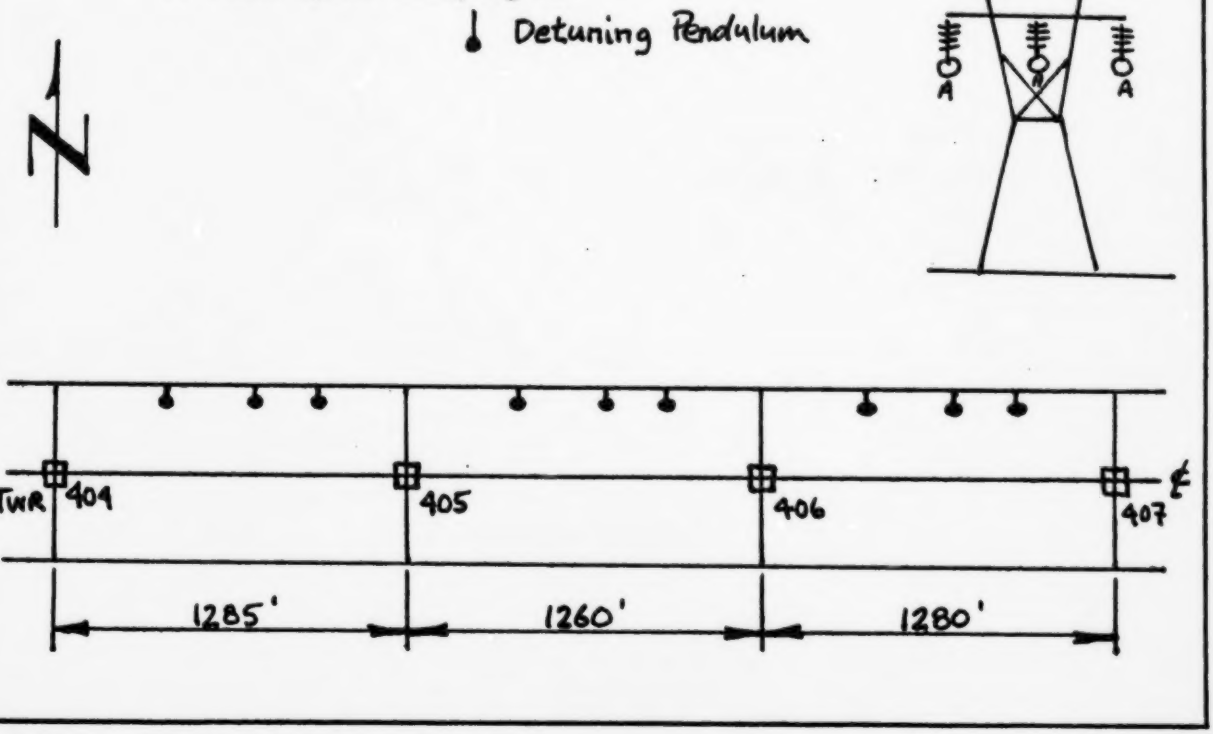
Air Temperature: _____

Ice Thickness (est'd): _____

General Weather Conditions: _____

Please provide Test Site Map

Indicate: 1) Wind Direction (↗)
2) Which Spans Galloping (X)



Return completed form to: C.J. Pon
Ontario Hydro Research Division
800 Kipling Avenue, KB223
Toronto, Ontario M8Z 5S4

86-221

DATA FROM FIELD OBSERVATIONS OF GALLOPING

OBSERVATION NO. S66 PAGE: 1 of 1 DATE: Jan. 22/86

UTILITY: Nova Scotia Power	SITE: Cheticamp	VOLTAGE: 12 kV	LINE DIR'N: N-S
CONDUCTOR NAME: ACSR-Quail	COND'R DIAMETER: 11.4 mm 0.447 in	COND'R CONST: 6/1	
CONDUCTOR SIZE: 2/0 kcmil	COND'R WT. 0.2731 kg/m 0.1831 lb/ft	AREA OF ALUM: 67.4 mm^2 0.1045 in^2	
NO OF SUBCONDUCTORS: 2	SUBCOND'R SPACING: - mm - in	AREA OF STEEL: 11.2 mm^2 0.0178 in^2	
TENSION AT 0°C 6.8 kN 1527 lb	TORS'L STIFF: 14.5 $N \cdot m^2/r$ 35 $lb \cdot ft^2/r$	ICE SHAPE, POSITION	
PENDULUM WT./SPAN: 5.6 kN 12.3 lb	NO OF LOCATIONS PER SPAN: 1		
PENDULUM ARM LENGTH: 234 mm 9.2 in	RADIUS OF GYRATION: 245 mm 9.7 in		
WEATHER: Freezing Rain/Sleet	WIND SPEED: 6.7-8.9 m/s 15-20 mph		
TEMPERATURE: 1 °C 34 °F	WIND DIRECTION: from NNE	ICE THICKNESS: 9.5 mm 3/8 in	

TIME	SPAN, TOWER NOs	SPAN LENGTH m ft	SAG m ft	GALLOPING AMPLITUDE: m ft NUMBER OF LOOPS								MAX'M THEOR AMPL. m ft	PROT'N LEVEL at $F_v = 1$, $F_t = 1$
				DET'D	REF	IPS	AFS	REF	REF	REF	REF		
				N *	M *	S *	*	*	*	*	*		
	All spans in site	Avg 39.6 130	.08 .25	0.3 1 1	0.3 1 2	0.15 0.5 2	0 0 0						>16

DET'D - Detuning Pendulum
IPS - Interhpase Spacer
AFS - Air Flow Spoiler
REF - Reference Phase

* PHASE LOCATION: N-North, S-South, E-East, W-West, U-Upper, M-Middle, L-Lower, I-Inner, O-Outer

M-360(a)

CEA DISTRIBUTION LINE GALLOPING OBSERVATION DATA SHEET

Utility Name: NOVA SCOTIA POWER CORP

Test Site Name: CHETICAMP

Date of Observation: _____

Observed by: _____

Conductor Size (s): 2/0 ACSR (0.447 inches dia.)

Wind Speed: _____

Wind Direction: from _____ to _____

Air Temperature: _____

Ice Thickness (est'd): _____

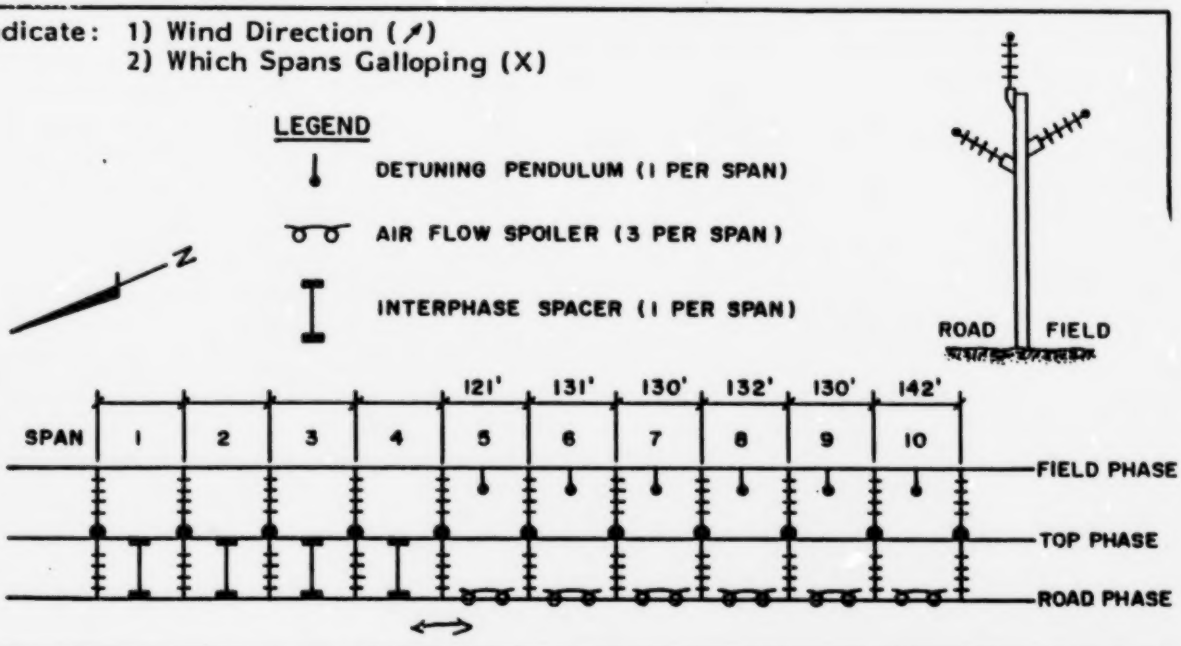
General Weather Conditions: _____

_____

_____

Please provide Test Site Map

Indicate: 1) Wind Direction (↗)
2) Which Spans Galloping (X)



TO CHETICAMP ROUTE 19 TO BELLECOTE

Return completed form to: C.J. Pon
Ontario Hydro Research Division
800 Kipling Avenue, KR28
Toronto, Ontario M8Z 5S4

86-221

DATA FROM FIELD OBSERVATIONS OF GALLOPING

OBSERVATION NO. B36 PAGE: 1 of 1 DATE: Jan. 24/86

UTILITY: Nvplem, Netherlands	SITE: Maalbroek - Beersdal	VOLTAGE: 150 kV	LINE DIR'N: NNE
CONDUCTOR NAME: ACSR-240	COND'R DIAMETER: 21.8 mm 0.858 in	COND'R CONST: 26/7	
CONDUCTOR SIZE: kcmil	COND'R WT. 0.985 kg/m 0.662 lb/ft	AREA OF ALUM: 240 mm^2 0.248 in^2	
NO OF SUBCONDUCTORS: 2 (vertical)	SUBCOND'R SPACING: 400 mm 15.75 in	AREA OF STEEL: 40 mm^2 0.062 in^2	
TENSION AT 0°C 11.6 kN 2600 lb	TORS'L STIFF: 124 $N \cdot m^2/r$ 300 $lb \cdot ft^2/r$	ICE SHAPE, POSITION	
PENDULUM WT./SPAN: 45 kN 100 lb	NO OF LOCATIONS PER SPAN: 4		
PENDULUM ARM LENGTH: 190.5 mm 7.5 in	RADIUS OF GYRATION: 275.8 mm 10.86 in		
WEATHER: Wet Snow	WIND SPEED: 10-15 m/s 22.5-34 mph		
TEMPERATURE: 1 °C 34 °F	WIND DIRECTION: N/A	ICE THICKNESS: 0.75 mm 0.3 in -2.7 -1.06	

TIME	SPAN, TOWER NOs	SPAN LENGTH m ft	SAG m ft	GALLOPING AMPLITUDE: m ft NUMBER OF LOOPS								MAX'M THEOR AMPL. m ft	PROT'N LEVEL at $F_v = 1$, $F_t = 1$
				DET'D	RCS	HS	DES	REF	AFS	REF	REF		
				*	*	*	*	*	*	*	*		
1:00 to 2:00 pm	87	325 1066	10 32.8	0 0 0	0 0 0	0 0 0	0 0 0	7.5 24.6 N/A	6.0 19.7 N/A				

DET'D - Detuning Pendulum
RCS - Rotating Clamp Spacer
HS - Hoop Spacer
DES - Despaced
AFS - Air Flow Spoiler
REF - Reference Phase

* PHASE LOCATION: N-North, S-South, E-East, W-West, U-Upper, M-Middle, L-Lower, I-Inner, O-Outer

DATA FROM FIELD OBSERVATIONS OF GALLOPING

OBSERVATION NO. B37 PAGE: 1 of 1 DATE: Late Jan/86
Early Feb/86

UTILITY: CEGB	SITE: Darwen to Bradford (2 circuits)	VOLTAGE: 400 kV 275	LINE DIR'N: E-W
CONDUCTOR NAME:	COND'R DIAMETER: mm in	COND'R CONST:	
CONDUCTOR SIZE: kcmil	COND'R WT. kg/m lb/ft	AREA OF ALUM: mm^2 in^2	
NO OF SUBCONDUCTORS: 4	SUBCOND'R SPACING: 400 mm 15.75 in	AREA OF STEEL: mm^2 in^2	
TENSION AT 0°C kN lb	TORS'L STIFF: $N\text{-}m^2/r$ $lb.ft^2/r$	ICE SHAPE, POSITION	
PENDULUM WT./SPAN: kN lb	NO OF LOCATIONS PER SPAN:		
PENDULUM ARM LENGTH: mm in	RADIUS OF GYRATION: mm in		
WEATHER: No Precipitation	WIND SPEED: 9.78 m/s 22 gusts mph		
TEMPERATURE: 0 °C 32 °F	WIND DIRECTION: N-E	ICE THICKNESS: mm	in

TIME	SPAN, TOWER NOs	SPAN LENGTH m ft	SAG m ft	GALLOPING AMPLITUDE: m ft NUMBER OF LOOPS								MAX'M THEOR AMPL. m ft	PROT'N LEVEL at $F_v = 1$, $F_t = 1$
				REF	REF	REF	REF	REF	REF	REF	REF		
				All Phases *	*	*	*	*	*	*	*		
Feb 1 am	78-145	about 305 1000		9.1 30 1									

Note: Galloping lasted for 4 - 5 days. This is not a test site.

REF - Reference Phase

* PHASE LOCATION: N-North, S-South, E-East, W-West, U-Upper, M-Middle, L-Lower, I-Inner, O-Outer

DATA FROM FIELD OBSERVATIONS OF GALLOPING

OBSERVATION NO. B38 PAGE: 1 of 1 DATE: Late Jan/86
Early Feb/86

UTILITY: CEGB	SITE: Darwen	VOLTAGE: kV	LINE DIR'N:
CONDUCTOR NAME:	COND'R DIAMETER: mm in	COND'R CONST:	
CONDUCTOR SIZE: kcmil	COND'R WT. kg/m lb/ft	AREA OF ALUM: mm^2 in^2	
NO OF SUBCONDUCTORS:	SUBCOND'R SPACING: mm in	AREA OF STEEL: mm^2 in^2	
TENSION AT 0°C kN lb	TORS'L STIFF: $N{\cdot}m^2/r$ $lb{\cdot}ft^2/r$	ICE SHAPE, POSITION	
PENDULUM WT./SPAN: kN lb	NO OF LOCATIONS PER SPAN:		
PENDULUM ARM LENGTH: mm in	RADIUS OF GYRATION: mm in		
WEATHER: No Precipitation	WIND SPEED: 8.9 - 13.3 m/s 20-30 mph		
TEMPERATURE: °C °F	WIND DIRECTION:	ICE THICKNESS: mm in	

TIME	SPAN, TOWER NOs	SPAN LENGTH m ft	SAG m ft	GALLOPING AMPLITUDE: m ft NUMBER OF LOOPS								MAX'M THEOR AMPL. m	PROT'N LEVEL at $F_v = 1$, $F_t = 1$
				DET'N	REF	REF	REF	REF	REF	REF	REF		
				U *	M *	L *	*	*	*	*	*		
		329		0	1.2	1.2							
				0	4	4							
		1080		0	2-3	2-3							

DET'D - Detuning Pendulum
REF - Reference Phase

* PHASE LOCATION: N-North, S-South, E-East, W-West, U-Upper, M-Middle, L-Lower, I-Inner, O-Outer

DATA FROM FIELD OBSERVATIONS OF GALLOPING

OBSERVATION NO. S67 PAGE: 1 of 1 DATE: Feb. 13/86

UTILITY: Ontario Hydro	SITE: O angeville Area	VOLTAGE: 7.2 kV	LINE DIR'N: E-W
CONDUCTOR NAME: ACSR-Pigeon	COND'R DIAMETER: 12.75 mm 0.502 in	COND'R CONST: 6/1	
CONDUCTOR SIZE: 3/0 kcmil	COND'R WT. 0.34 kg/m 0.2309 lb/ft	AREA OF ALUM: 85 mm^2 0.1318 in^2	
NO OF SUBCONDUCTORS: 1	SUBCOND'R SPACING: - mm - in	AREA OF STEEL: 14.2 mm^2 0.022 in^2	
TENSION AT 0°C kN lb	TORS'L STIFF: $N \cdot m^2/r$ $lb \cdot ft^2/r$	ICE SHAPE, POSITION	
PENDULUM WT./SPAN: kN lb	NO OF LOCATIONS PER SPAN:		
PENDULUM ARM LENGTH: mm in	RADIUS OF GYRATION: mm in		
WEATHER:	WIND SPEED: 4.4 m/s 10 gusts mph		
TEMPERATURE: -10 °C 14 °F	WIND DIRECTION: from NW	ICE THICKNESS: 12.7-19 mm 1/2-3/4 in	

TIME	SPAN, TOWER NOs	SPAN LENGTH m ft	SAG m ft	GALLOPING AMPLITUDE: m ft NUMBER OF LOOPS								MAX'M THEOR AMPL. m	PROT'N LEVEL at $F_v = 1$, $F_t = 1$
				REF *	REF *	REF *	REF *	REF *	REF *	REF *	REF *		
9:40 am		90 295		0.76 2.5 1									
10:00 am		75 246		0.91 3 1									

REF - Reference Phase

* PHASE LOCATION: N-North, S-South, E-East, W-West, U-Upper, M-Middle, L-Lower, I-Inner, O-Outer

DATA FROM FIELD OBSERVATIONS OF GALLOPING

OBSERVATION NO. S68 PAGE: 1 of 1 DATE: Mar. 6/86

UTILITY: Newfoundland Light and Power	SITE: OPL-Ø2	VOLTAGE: 12.5 kV	LINE DIR'N:
CONDUCTOR NAME: AASC-Avvidal	COND'R DIAMETER: 14.1 mm .557 in	COND'R CONST:	
CONDUCTOR SIZE: #4/0 kcmil	COND'R WT. kg/m lb/ft	AREA OF ALUM: mm^2 in^2	
NO OF SUBCONDUCTORS: 1	SUBCOND'R SPACING: - mm - in	AREA OF STEEL: - mm^2 - in^2	
TENSION AT 0°C 5.02 kN 1128 lb	TORS'L STIFF: $N \cdot m^2/r$ $lb \cdot ft^2/r$	ICE SHAPE, POSITION	
PENDULUM WT./SPAN: - kN - lb	NO OF LOCATIONS PER SPAN: -		
PENDULUM ARM LENGTH: - mm - in	RADIUS OF GYRATION: - mm - in		
WEATHER: Overcast	WIND SPEED: 32.8 m/s 74 mph		
TEMPERATURE: -2 °C 28.4 °F	WIND DIRECTION: from N-W	ICE THICKNESS: Ø mm Ø in	

TIME	SPAN, TOWER NOs	SPAN LENGTH m ft	SAG m ft	GALLOPING AMPLITUDE: m ft NUMBER OF LOOPS								MAX'M THEOR AMPL. m	PROT'N LEVEL at $F_v = 1$, $F_t = 1$
				AFS	REF	REF	REF	REF	REF	REF	REF		
				M *	* Field	* Road	*	*	*	*	*		
4:00 pm	4-5	61 200		0 0 0	.25 .83 2	.25 .83 2							

AFS - Air Flow Spoiler
REF - Reference Phase

* PHASE LOCATION: N-North, S-South, E-East, W-West, U-Upper, M-Middle, L-Lower, I-Inner, O-Outer